

Sound Pressure Level (SPL) Meter

the king-sized model

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The measuring instrument described here distinguishes itself in one respect from all the others in its species. The display has been implemented in such a way that is – without exaggeration – not easily overlooked. This opens up entirely new possibilities for its application.

The most salient feature of this circuit is that the display consists of a panel made from 10 incandescent lamps. This immediately catches the eye, and at the same time it is obvious that we're dealing with a novel kind of measuring instrument. A typical sound

pressure or VU meter makes use of a much more modest LED or moving coil indicator.

So what is the point of this oversized display? Has it been added just for fun? Well, yes and no. Obvi-

ously, a display such as this begs to be used in discos and with parties, where it can function as a light show to provide an optical setting for the music. We expect that this circuit will be popular in these circles.

But that is not the purpose for which this piece of electronics was originally designed. The most important application that we had in mind initially, was to provide a clear indication of the sound-pressure level in workshops, party halls and discos – in short, any place where extended exposure to excessive sound levels is likely to lead to hearing loss.

Design

The design of a sound pressure level (SPL) meter is in reality not all that difficult. In addition to a microphone, there is, strictly speaking, not much more required than an amplifier stage, a rectifier and a display. Also, to adapt the indication to the human hearing response, it is desirable to add an A-weighted filter, while in our case, we had to add lamp drivers as well.

A brief glance at the circuit shown in **Figure 1** makes the design of the circuit clear. A bird's eye perspective: the sound is picked up with the aid



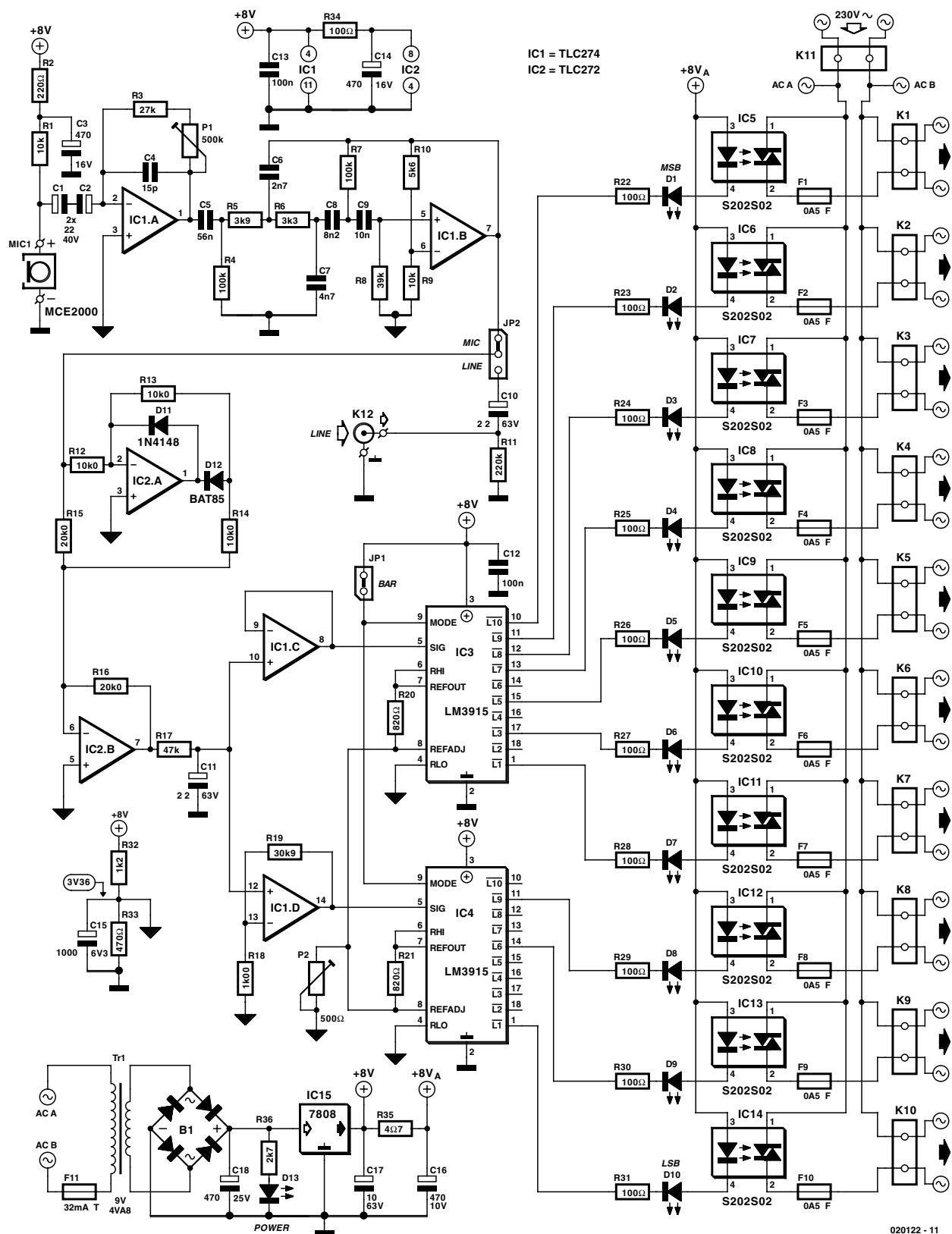


Figure 1. The circuit comprises a microphone amplifier, a filter, a rectifier and a display. The usual LED scale has been extended here with incandescent lamp drivers.

of an electret microphone cartridge (MIC1), amplified (IC1a) and filtered (IC1b). This is followed by a full-wave rectifier (IC2) after which the signal is averaged (R17/C11) and buffered/amplified (IC1c/IC1d). The signal is then presented to two display drivers type LM3915 (IC3/IC4), which have been designed to drive LED indicators directly. Each of the total of ten LEDs is connected in series with an opto-triac (IC5 through IC14). It is the opto-triac's task to switch the lamps connected to K1 through to K10.

The sensitivity can be adjusted with P1. By changing JP2 to the other position it is possible to replace the microphone signal with a line signal that may be connected to K12. The latter option is likely to be used when the circuit is used as a light show in PA installations. If the meter is used in this way on a permanent basis, then the microphone and IC1 plus surrounding parts can be omitted.

We have now shed some light on the essence of the circuit. But, as usual, there are a number of details, which are worth mentioning. So we will now take a closer look at the various parts of the circuit.

Microphone amplifier

The microphone selected for this project is a small electret cartridge, type number MCE-2000 from Monacor (Monarch). Other comparable cartridges are likely to work without problems as well.

The electret microphone receives its supply voltage via R1. R2/C3 suppress any disturbances that may be present on the supply rail. Without the filter, these disturbances would be significantly amplified by IC1a. The amplification of the microphone signal is defined by the ratio of the output impedance of the electret cartridge and R1, as well as the value of P1 plus R3. The value of resistor R3 has been selected in such a way as to provide an adjustment range of about 26 dB for P1.

When making absolute sound pressure measurements, it is important to know what the calibration levels are. When the amplification of IC1a is set to maximum with P1, and P2 is set to '0', full-scale deflection corresponds to a level of about 90 dBA. This was very conscious decision, because this sound pressure marks the beginning of the danger zone for hearing loss.

A few more details. The (FET) output of the electret cartridge is at a constant potential via C1/C2. This improves the drive range and makes a slightly higher value of R1 possible. Opamp IC1a therefore operates as a current to voltage converter. C4 eliminates possible RF-disturbances at the highest amplification and limits the bandwidth to

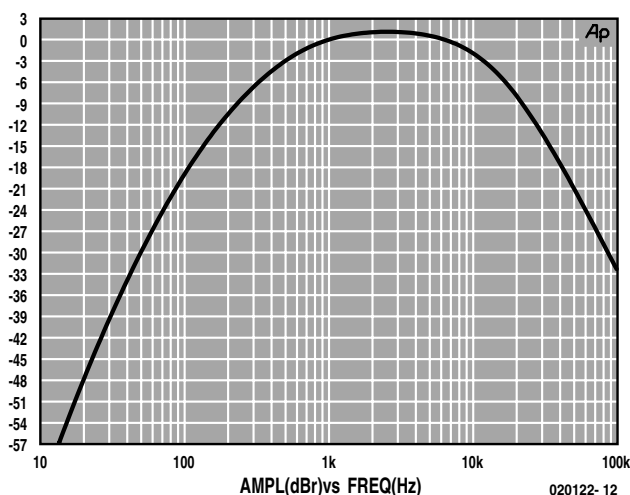


Figure 2. The transfer function of the A-weighted filter has a maximum at a frequency of around 3 kHz to mimic typical human hearing response.

about 20 kHz.

The option of changing jumper JP2 to the other position and connecting a line signal to K12 has already been mentioned previously. The microphone and microphone amplifier are then ignored.

Filter

The so-called 'A-weighted filter' is used both in sound measurements as well as in audio technology when measuring the signal to noise ratio. The essence of this type of filter is to modify the measuring spectrum so that it corresponds to the characteristics of human hearing. The sensitivity of the ear reaches a maximum at around 3 kHz and drops quickly above and below this frequency. The A-weighted filter is therefore designed in such a way that its maximum also occurs at about 3 kHz. **Figure 2** shows the transfer function of the filter. To simplify the construction of the filter, only ordinary components from the E12-series have been used. Despite this, we have been able to match the transfer function to within about ± 1 dB of the theoretical model.

Rectifier

To make a full-wave rectifier, a standard circuit with two opamps has been used. The 'negative' signal from the half-wave rectifier IC2a is amplified by a factor of two by IC2b

and summed to the input signal to create a full-wave rectifier. A Schottky diode has been used for D12 because it has a lower threshold voltage, resulting in better linearity and a greater bandwidth. The disadvantage is that these diodes have a higher leakage current, and for this reason a normal diode has been used for D11.

R17 and C11 average the rectified signal with a time constant of about 0.1 second. This may well result in an indicator that reacts a little too quickly, but it does produce a better indication of the peaks. The time constant can be increased, if desired, by increasing the value of C11 (there is probably enough space on the PCB for a small 100 μ F, 10 V electrolytic capacitor).

Display drivers

In order to drive the display, two ICs of the type LM3915 have been used. To dedicated *Elektor Electronics* readers this device will certainly be well known. If you are unfamiliar with this IC, suffice it to say that the LM3915 was designed to display a varying input signal directly on an LED bar graph. Internally, the IC has 10 comparators, the inverting inputs of which are tied together to the output of an internal buffer/amplifier. Each of the non-inverting comparator inputs is connected to a tap on a ladder-shaped potential divider, which generates the various refer-

ence voltages. The following applies to each comparator: as soon as the potential at the inverting input is higher than the reference voltage on the non-inverting input, the output level will go 'low' and the corresponding LED will come on. Why then, do we need two LM3915, when one IC would have been sufficient to drive 10 LEDs? There are two reasons. The first is that a simple rectifier is not very linear at the low end of the range and this can be corrected by selecting specific outputs. The second is that we also want the circuit to indicate low levels of sound pressure. **Table 1** shows the relationship between the theoretical value and the actually measured value on the prototype (measured at 1 kHz). The table also indicates that the sound-pressure meter has a range of 48 dB, which will be sufficient in most cases.

Stretching the scale over two LM3915 is made possible by ampli-

fying the measured value found at C11 by an extra 30 dB for IC4. In all other respects the adjustments for IC3 and IC4 are equal. A simple virtual ground has been created with R32/R33/C15 for the entire circuit. This is also the lower reference value (RLO) for the potential dividers in both ICs. This voltage level was chosen such that, at full drive level, the output of IC2b will saturate symmetrically. The top of the potential dividers (RHI) is connected to the LM3915's internal reference (REFOUT). It is possible that because of the small variations between individual devices (tolerance) the scales do not join exactly. This is of no consequence in this application.

The sensitivity of IC3 and IC4 is greatest when the voltage level at REFADJ is equal to the virtual ground potential (P2 at 0 Ω). This pin has been connected to both ICs so that this level can be adjusted

with a potentiometer. It is possible, for example, to calibrate the circuit with P2 to a 2-V full-scale signal (the output of a CD player or similar). The internal reference voltage is then typically 1.28 V.

With a pure sine wave this equates to a sensitivity of $1.42 V_{\text{rms}} (1.28 \times \pi) / 2\sqrt{2}$.

Lamp drivers

The trigger current for the opto-triacs that have been utilised here is 8 mA minimum and 50 mA maximum. To create a comfortable operating margin, the trigger current has been set to 16 mA and is therefore a little higher than strictly necessary ($10 \pm 1.28 V/R20$). To make checking easier, an LED with series resistor is also connected to each of the trigger inputs, so it is possible to see if the drive to the opto-triacs is correct without having to connect any lamps. The resistors are mainly intended to limit the dissipation of the LM3915, but they also make it possible to check the trigger current.

A nice feature of the LM3915 is that pin 9 allows a selection to be made between bar- and dot-mode. This can be achieved by changing JP1. When two LM3915s are cascaded, and dot-mode is selected, it is normally necessary to use a trick to turn off the MSB LED of the 'lower' LM3915. But since this output is not actually used it is not necessary here.

Practical matters

The printed circuit board designed for the sound pressure meter is shown in **Figure 3**. Because of the 10 sets of screw terminals for the lamps and the same number of fuses and opto-triacs, the size of the PCB is quite large. This does not mean however, that it is a cumbersome size to deal with. On closer exami-

Sound pressure

We now have a fine measuring instrument, but what criteria do we use when making measurements? What is a normal sound pressure and when is there a risk of hearing loss?

The table below lists a number of typical values in dB(A). In this summary do not confuse the pain threshold with the level at which hearing loss may occur. The latter is typically at 80 dB(A). Employers are legally required to provide hearing protection when the sound pressure is continuously above this level in the working environment. At higher levels the risk of hearing loss increases rapidly; at a sound-pressure of 90 dB damage can occur after 1 hour, while at 95 dB(A) the time is reduced to just 15 minutes. The table makes it clear that for visitors of rock concerts it is no unnecessary luxury to provide for some kind of hearing protection!

120 dB(A)	pain threshold
110 dB(A)	live rock concert
100 dB(A)	bench saw
90 dB(A)	passing train
80 dB(A)	motorway traffic
70 dB(A)	vacuum cleaner
60 dB(A)	normal conversation
50 dB(A)	quiet street
40 dB(A)	quiet room
30 dB(A)	library
20 dB(A)	rustling leaves
0 dB(A)	hearing threshold

With the circuit described here, 'full-scale' corresponds to a level of 90 dB(A) when P1 is set to maximum amplification and P2 is set to 0 Ω. If you would like to change that, or if you have a different microphone cartridge, then the sensitivity of the instrument will have to be adjusted with the aid of a calibrated sound-pressure meter.

Table 1

Relationship between theoretical and actual sound pressure values.

LED	theoretical [dB]	measured [dB]	
D1	0	0	MSB
D2	-3	-3	
D3	-6	-6	
D4	-9	-9	
D5	-15	-16	
D6	-21	-22	
D7	-27	-28	
D8	-33	-33	
D9	-42	-40	
D10	-57	-48	LSB

nation, the number of parts that make up the circuit is quite reasonable and since the layout is very straightforward, even less experienced hobbyists should not encounter insur-

mountable problems. If you stick to what the PCB overlay and parts list prescribe and do not mix up any resistor values, it's unlikely anything

goes wrong.

It is of course easiest to start with the low profile components followed by the taller ones. Finish by fitting

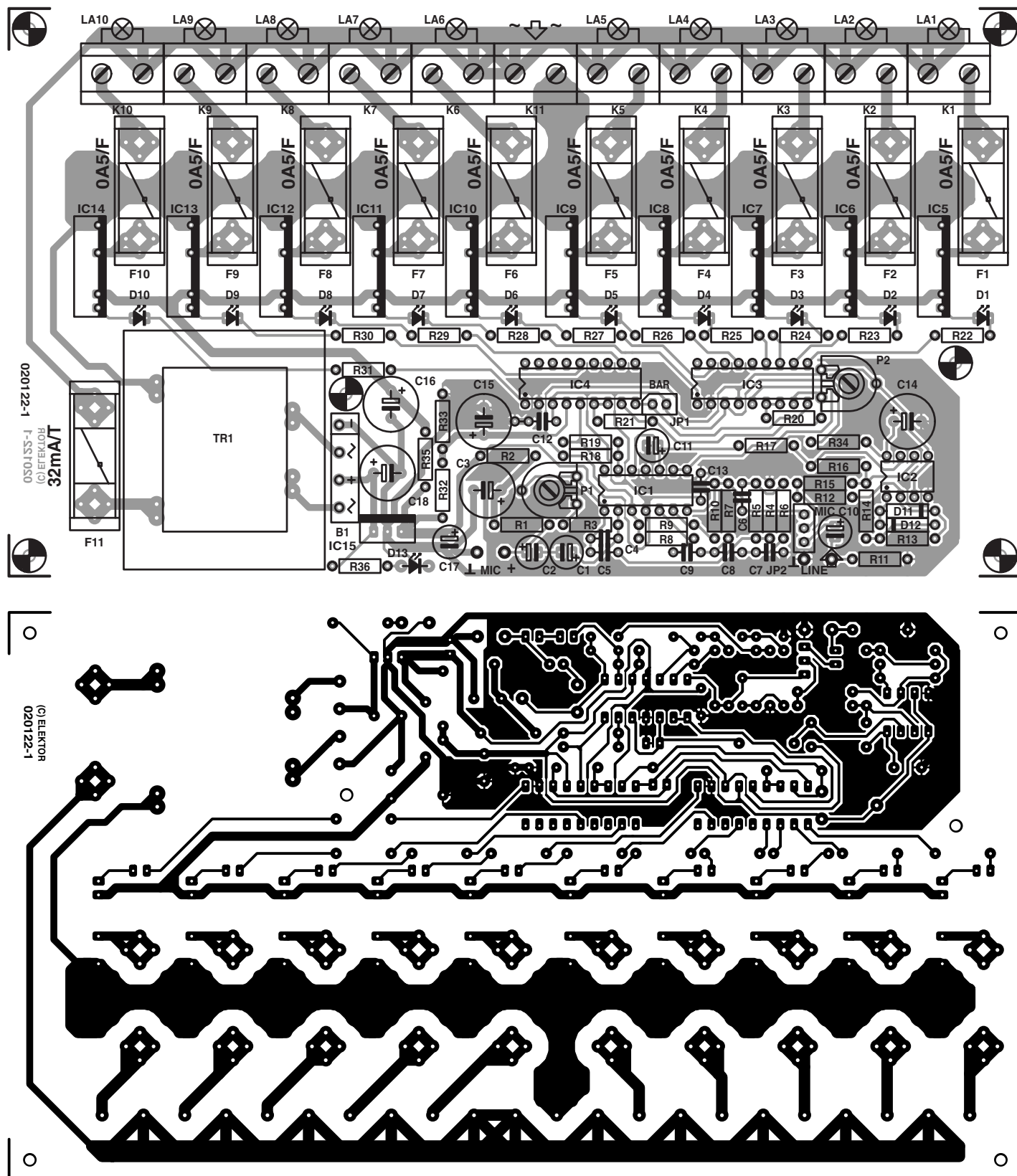


Figure 3. The PCB is dominated by the 10 opto-triacs, the fuses and the connectors for the lamps.

the screw terminals, opto-triacs and power transformer. The ICs are mounted in sockets.

The PCB layout has been designed for Class-II electrical isolation — the opto-triacs, too, easily conform to the standard (4000 V_{rms} isolation!).

In order to simplify the construction as much as possible, the power supply for the circuit, including the transformer, is also mounted on the PCB. As can be seen in the schematic of **Figure 1**, the power supply follows the standard recipe of 4.8-VA transformer, bridge rectifier (note the order of the connections), filter capacitor and 8-V regulator

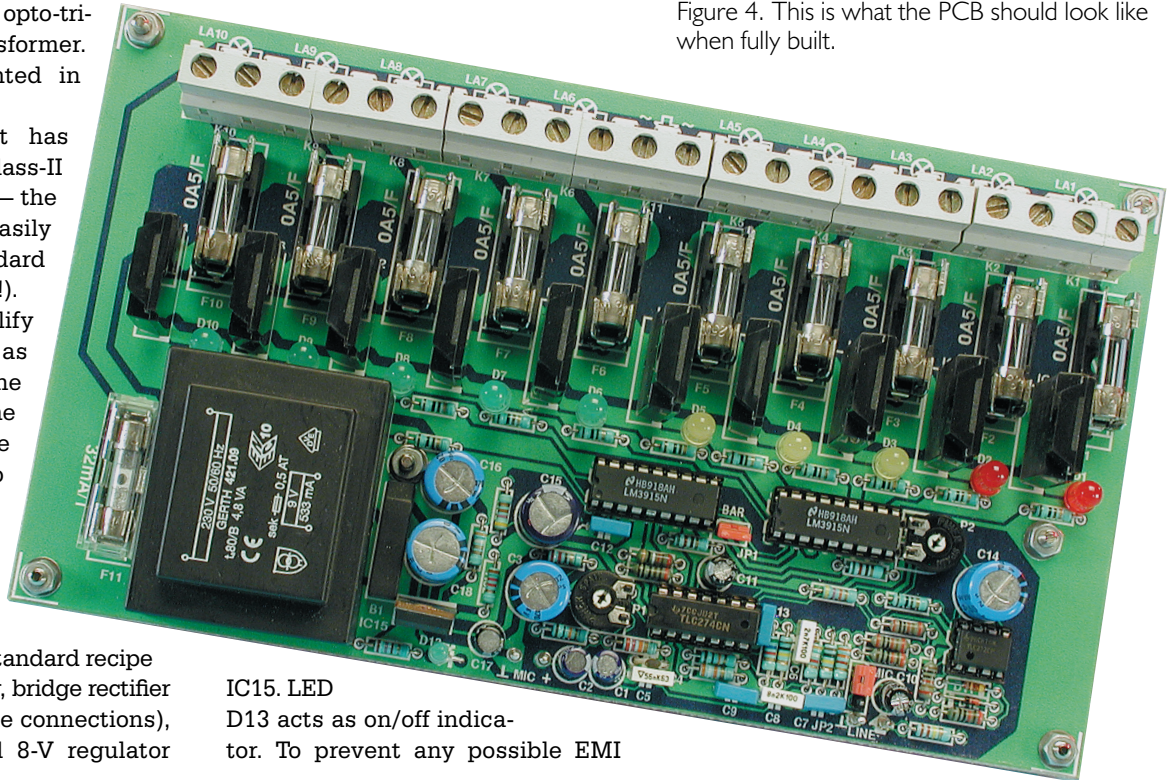


Figure 4. This is what the PCB should look like when fully built.

IC15. LED

D13 acts as on/off indicator. To prevent any possible EMI

COMPONENTS LIST

Resistors:

R1, R9 = 10k Ω
 R2 = 220 Ω
 R3 = 27k Ω
 R4, R7 = 100k Ω
 R5 = 3k Ω
 R6 = 3k Ω
 R8 = 39k Ω
 R10 = 5k Ω
 R11 = 220k Ω
 R12, R13, R14 = 10k Ω
 R15, R16 = 20k Ω
 R17 = 47k Ω
 R18 = 1k Ω
 R19 = 30k Ω
 R20, R21 = 820 Ω
 R22-R31, R34 = 100 Ω
 R32 = 1k Ω
 R33 = 470 Ω
 R35 = 4 Ω
 R36 = 2k Ω
 P1 = 500k Ω preset
 P2 = 500 Ω preset

Capacitors:

C1, C2 = 22 μ F 40V radial
 C3, C14 = 470 μ F 16V radial
 C4 = 15pF
 C5 = 56nF, lead pitch 5mm
 C6 = 2n7, lead pitch 5mm
 C7 = 4n7, lead pitch 5mm
 C8 = 8n2, lead pitch 5mm
 C9 = 10 n, lead pitch 5mm
 C10, C11 = 2 μ F 63V radial

C12 = 100nF
 C13 = 100nF, lead pitch 5mm
 C15 = 1000 μ F 6V3 radial
 C16 = 470 μ F 10V radial
 C17 = 10 μ F 63V radial
 C18 = 470 μ F 25V radial

Semiconductors:

D1-D10 = LED, red (no high-efficiency type)
 D11 = IN4148
 D12 = BAT85
 D13 = LED, green (high-efficiency)
 IC1 = TLC274
 IC2 = TLC272
 IC3, IC4 = LM3915
 IC5...IC14 = S202S02 (Sharp)
 IC15 = 7808

Miscellaneous:

JPI = 2-way pinheader w. jumper
 JP2 = 3-way pinheader w. jumper
 K1-K11 = 2-way PCB terminal block, lead pitch 7.5 mm
 K12 = cinch socket, chassis mounting
 Tr1 = 9V 4VA8 e.g., Gerth 421.09
 B1 = B80C1500 in rectangular case (80V piv, 1.5A peak)
 F1-F10 = fuse, 500mA, fast, with PCB mount holder
 MIC1 = MCE2000 (Monacor/Monarch) or equivalent
 F11 = fuse, 32 mA, slow, with PCB mount holder
 PCB, order code **020122-1** (see Readers Services page)

problems, it is recommended to use a sizeable mains filter (minimum 5 A load rating!). Finally a few comments related to the enclosure for the circuit. There is no argument that with safety in mind, a plastic enclosure is preferable. Various enclosures can be found that are suitable for the size of this PCB. If you choose a version made from translucent plastic then the LEDs will still be visible from the outside. In the case of a non-transparent plastic case, it is also possible to lengthen the leads of the LEDs and mount these indicators on a panel visible from the outside. On the prototype, just for fun, we actually used different colours for the LEDs: red for D1 and D2, yellow (amber) for D3 to D5 and green for D6 to D10.

Pay close attention when fitting and wiring the circuit into an enclosure that no undesirable short-circuits can occur and provide a suitable mains entry connector or strain relief for the mains cable. To avoid an unnecessary search for the screw terminals for the mains cable, we will quickly mention here that it can be found exactly in the middle among the lamp connectors. The enclosure needs to be well ventilated if the circuit is to be used continuously at full signal and the maximum load is connected to each output (max. 100 W for each lamp!). This is because IC5 through IC14 dissipate quite a bit of heat when they have to switch a lot of power.

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